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Migration flyways of geese in Central Siberia

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Abstract. Observations of geese abundance and migration in Central Siberia are especially relevant for international scientists due to the lack of objective data on this topic in English literature. The goal of this paper is to summarize the results of a long-term study (1980-2016) on migration of geese in Central Siberia, to distinguish and describe their migration routes in the environment of Continental Asia. The authors used a methodological complex comprising universally accepted techniques of ornithological studies, such as visual and instrumental observations at staging sites and along geese migration routes, registration of birds on the ground (travelling on foot, by boat or by car) and in the air (using aircraft). To clarify the subspecies, the authors carried out collection of birds or their body parts (heads, wings, legs, n = 1032 units). Capture and banding of nesting geese was done in the Altai-Sayan Ecoregion. The places and dates of maximum geese concentration, as well as the time of their departure, are quite permanent; that made it possible to carry out their definite registration using aircraft (25.5 thousand km). The works at each of the most significant sites were performed annually, at the same time of the year. They also analyzed data available in scientific literature and reports on returns of rings from the Ringing Center of the Russian Academy of Sciences, as well as information about geese received from hunters and specialists of environmental services. The paper shows main migration routes and their territorial connections. The Great Lakes Depression in Mongolia is a kind of “migration dead end” for a great number of waterfowl migrating in spring.

1. Introduction

Central Siberia is a global crossroads for migratory birds. It is adjacent to Inner Asia - the most important center of speciation and a grand biogeographical barrier; it plays an important role in the study of birds and pathogens associated with them. Until recently, information on migration of Siberian bird in Continental Asia was fragmentary, and researchers often expressed diametrically opposite judgments.

Extensive studies of bird migration were made on the territory of Central Siberia in 1980-2016. However, their results have not yet been translated into English and published internationally. The global ornithological community still perceives Central Siberia as a “white spot” [12, 13, 25, 30, 38, 39, 46]. Geese, traditionally important for hunters, certainly deserve particular attention as an important biological resource. The southern part of the region is a nesting place for Eastern Siberian taiga bean goose (*A. fabalis middendorffii* Severtsov, 1873), Eastern Eurasian graylag goose (*A.*



anser rubrirostris Swinhoe, 1871), bar-headed goose (*A. indicus*) geese, and swan goose (*A. cygnoides*). In migration periods, West Siberian tundra bean goose (*A. fabalis rossicus* Buturlin, 1933) is predominant.

However, the events of recent decades have brought cardinal changes; today it is more important to talk about conservation measures for some species and their populations. The geese inhabiting the south of Central Siberia are currently experiencing a serious impact of anthropogenic factors, which leads to fragmentation and reduction of their habitats, and to a decrease in their abundance. Most of the species, subspecies and subpopulations of geese were included in the regional Red Lists of Threatened Species [26, 27, 28, 29].

The densely populated Asian continent comprises transcontinental bird migration routes that cross all natural landscape zones. Thus, it plays a special role in occurrence and global transmission of especially dangerous infections related to water and swamp birds [12, 45, 36]. In this sense, studies of the geese migration range structure are important not only in terms of environment, but also in terms of people's safety. The goal of this study was to compile the results of long-term observations (1980-2016) of geese migration in Central Siberia, as well as to distinguish and describe their migration routes in Continental Asia.

2. Materials and methods

The research materials for this work were the observations made by the authors and the staff of the Hunting and Reserve Resources Chair of Siberian Federal University (Krasnoyarsk, Russia). The research on geese migration in Central Siberia began in 1980. The total length of the itineraries was more than 60 thousand km, including 34.5 thousand km on land and 25.5 thousand km with the use of aviation. Stationary research was usually carried out at key sites. However, for the calculation of the total migration flow, the observation points were partly located outside of the congregation sites of migratory birds. Visual-optical and acoustic-optical observations were made in 91 point, ancillary registration of geese at their staging site – near 132 reservoirs. The total duration of geese registration along flyways and at staging sites was more than 15 thousand hours in the daytime (visual and instrumental observations) and 1422 hours at night (acoustic-optical observations).

The peculiarity of South-Central Siberia is that in spring, in the latitudes between 51 and 56°N, northern geese make a long (up to 45-50 days) stop before flying to the nesting grounds situated in taiga and tundra zones. The places and dates of maximal geese concentration, as well as the time of their departure, are quite constant. That allows making a full and definite registration, similar to bird count in wintering areas. In case of aerial survey, it was possible to count almost all individuals throughout the entire territory at once. Until 2006, birds were counted across the major part of the wetlands located in the south of Central Siberia. After identification of key stops and geese concentration, observations were made mainly in Khakassia and in the southern part of Krasnoyarsk Krai. The works at each of the most significant sites were performed annually, at the same time of the year. The works were carried out in April-May and September-October, with obligatory adherence to the periods of bird maximal concentration; according to average long-term data, such periods are May 9-15 (± 3 days) in spring and October 7-15 (± 3 days) in autumn.

In the Tuva Republic, considerable geese stopping places are preserved only in the eastern and southern parts; the key areas of migratory birds are still such lakes as Khadyn, Tore-Khol and Ubsunur. They were visited recurrently for registration and collection of survey information from local residents (hunters, biology teachers, biology students, including the students of the Hunting and Reserve Resources Chair at Siberian Federal University, hunting inspectors and representatives of other environment protection organizations).

The study of bird migration was conducted with the help of a devised methodological complex [36], which was adjusted taking into account available technical equipment. This complex includes visual-instrumental (day-time) and acoustic-optical (night-time) observations, bird capture, examination of living birds, aerial, car, boat and walking tracking, bird count at the sites of their congregation, registration of transit-flying bird flocks, as well as computer processing and data

analysis. In drawing up the maps of the routes, we used field observations, available literature sources [9, 14, 17, 19, 20, 21, 42] and data from the Ringing Center of RAS and information on found birds from local residents.

To clarify the subspecies of geese, we carried out collection of birds or their body parts (heads, wings, legs); the total number of considered units is equal to 1032. In the last years of observations, video recording and photography at the places of bird concentration played an important role in collecting required information in the field. The number of photographs and video records of individual birds and geese congregations reached 12.9 thousand.

3. Results

According to various estimates, researchers distinguish 5 to 8 or more flyways in Asia [8, 18, 22, 24, and others]. We believe that there are two main continental migration routes passing through the south of Central Siberia – Eastern Asian-African (17.3 thousand km) and Western Asian-Australasian (15.8 thousand km). The first route starts in the outermost northeast of Asia or even in Alaska, the second one – in the north of Eastern Europe. The Central-Asian route, which is used by the geese migrating through the south of Central Siberia (it is frequently mentioned in domestic and foreign literature), belongs to the category of the II order.

Basing on the obtained data and analysis of available information, we prepared a general map for the migration territory of Inner Asia's birds and its adjacent areas, with allocation of the following migration routes: Kazakhstan-Central Siberian (1) Ubsunur-Tarim (2) Ubsunur Gobi-Qinghai (3), East Tuva-Khubsugul-Chinese (4), Angara-Baikal-Gobi (5) and Tunguska -Baikal-Angara-Khingan (6) (figure 1).

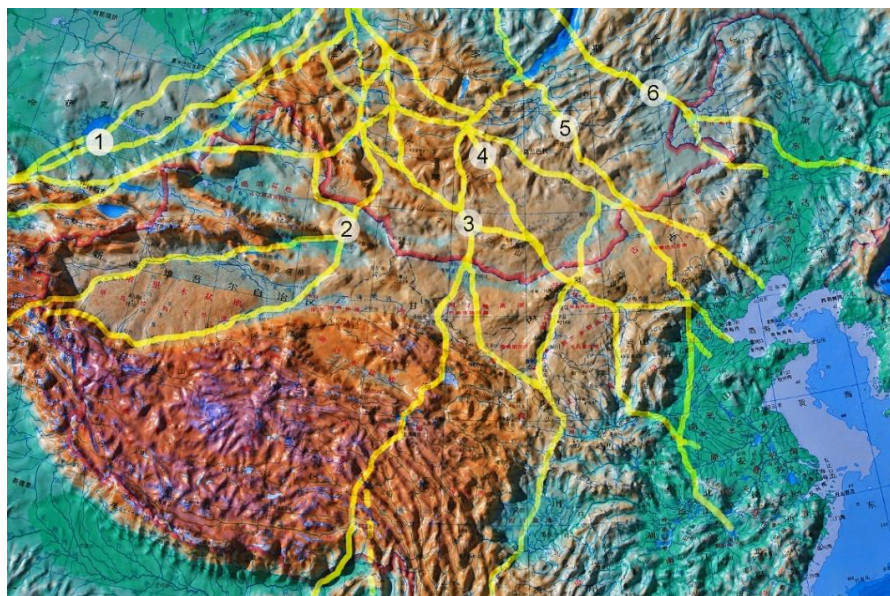


Figure 1. Migration routes of birds in Inner Asia: Kazakhstan-Central Siberian (1) Ubsunur-Tarim (2) Ubsunur Gobi-Qinghai (3), East Tuva-Khubsugul-Chinese (4), Angara-Baikal-Gobi (5) and Tunguska -Baikal-Angara-Khingan (6).

The particular features of flyways trajectories and the migration area structure in the considered territory become clearly visible in the example of such species as *Anser albifrons* and *Anser fabalis*. Their migrations are very noticeable along the valleys of large water streams – the Yenisei and Angara Rivers. The Yenisei mainline flyway forms a number of branches, primarily to the southwest, partly south and southeast directions. At that, many bird migration routes (Eastern-Evenk, Taz- and Ob-Yenisei flyways) run along watershed interfluvial areas; flying along these areas, birds usually do not follow the landscape patterns.

The typical «non-valley» migration routes of waterfowl birds are quite clearly visible in the eastern part of Central Siberia, in Evenkia and the territory bordered by the Yenisei and Angara rivers

(Zaangarie). They are the extensions of the Angara-Yenisei and Evenk branches of the Khingan migration route made by the birds of the wetland complex of the Palearctic eastern part.

The wintering areas of white-fronted geese and bean geese are located both in the western (Germany, the Netherlands, Hungary, Yugoslavia, Italy, the northern part of Spain, etc.) and eastern (China, South Korea, Japan) parts of Eurasia. East Asia, primarily China, is the wintering area for swan geese. Graylag and bar-headed geese winter in South Asia (India, Pakistan, partly Indochina); some portion of white-fronted and graylag geese, as well as lesser white-fronted geese (their West-Palearctic population) spend winters in the south of the Caspian Sea and in Middle and West Asia [3, 16, 38, 46].

The flyways of white-fronted geese that nest in Taimyr are directed to the west and southwest. They mainly stop at the places located close to the water reservoirs of Northern Kazakhstan and the North Caucasus. In the south of Krasnoyarsk Krai, in Khakassia and Tuva, we found only small groups of migratory white-fronted geese that use the migration routes of taiga bean geese. Let us consider the migration routes of bean geese subspecies.

Anser fabalis rossicus subspecies flies towards «West-European» and «East-Asian» wintering grounds along the following main routes:

I. The typical tundra zones of the Yenisei Gulf, West Taimyr, Gydan and Yamal -Malozemelskaya, Bolshezemelskaya tundra zones – the White Sea-Baltic corridor – Estonia – the southeast of Finland – West Poland, the east of Germany or polders in the Netherlands.

II. The tundra regions of the Gydan, Tazovskiy peninsula, partly the Lower Yenisei Region and West Taimyr – the junction of the Ob and Irtysh Rivers – the Middle Volga Region – the northern part of Russia's south – the east and central parts of Ukraine – the Pannonian Basin.

III. The West and Central Taimyr – the valley and bottom land of the Lower Yenisei River – the Lower Angara River – the Kansk Hollow – the upper part of the Bratsk Reservoir –Balaganskaya forest-steppe (the upper reaches of the Angara River) – Lake Baikal – the delta and valley of the Selenga River – the valley of the Tola River – the middle course of the Yellow (Huang He) River – Hubei – Lake Dongting (Hunan province).

IV. The Tundra zones of West Siberia – the valley and bottom land of the Ob River – the Chulym River Basin – the Minusinsk Hollow – the Upper Yenisei River – Khangai – the middle course of the Huang He – Hubei - Lake Dongting (Hunan province).

V. The East Taimyr – the south part of the North-Siberian Lowland – the Kotuy River Basin – the upper and middle courses of the Lower Tunguska River – the upper reaches of the Lena River –the northern part of Lake Baikal – the Barguzin Hollow – the lakes of the Eravinskiy and Arahleiskiy Regions – Dauria – Torey Lakes, Lake Dalai-Nur and the the Argun River basin – the Khingan Range – the water reservoirs if Inner Mongolia - the lower reaches of the Yangtze River.

Anser fabalis fabalis subspecies mostly migrates along the more western routes:

- The west regions of the White Sea and the Kola Peninsula – the Scandinavian Peninsula, the southern part of Sweden, Denmark.
- The North-Taiga regions of the basins of the Ob, Taz and the left bank of the Yenisei Rivers – reservoirs of Zauralie – Volga-Kamskiy Region – the southern part of North-West Russia – Baltic countries – the northern part of Belarus – the seaside regions of the Baltic coast of Poland and North-East Germany – the north of the Netherlands.
- The south of the Turukhan valley – the Middle-Taiga regions of the Yenisei-Ob interfluvium / the river basins of the western flank of the Central Siberian Plateau – the northern part of Khakassiya and Kemerovo Region – the Ob River – the Novosibirsk Reservoir – the southwest part of steppe Altai – the Gilevo Reservoir – the Irtysh River – Lake Zaysan – Zhetysay and the south of Kazakhstan - Lake Issyk-Kul – the southwest of Xinjiang Uyghur Autonomous Region (West China).

To our opinion, the latter wintering route is used by the bean geese inhabiting the basins of the taiga's rivers of the Ob-Yenisei interfluvies –the Ket, Tym, Sym, Elogui, Dubches Rivers, etc.

On the wintering grounds in East Asia, numerous tundra bean geese (*A.f. rossicus* и *A.f. serrirostris*) gather in the basin of the Yangtze River's lower reaches (Poyang, Dongting, Shenzhen Lakes, etc.). East tundra bean geese (*A.f. middendorffii*) and partly the birds of the East-Siberian tundra subspecies (*A.f. serrirostris*) are more frequent in the seaside regions of China, near Lake Dongting, as well as in South Korea and Japan [1, 2, 11, 16, 44]. We found that the westernmost migration routes are used by the «south-Asian» west tundra bean geese, nesting sites of which are located both in Taimyr and Gydan and, possibly, in more western locations, including the Tazovskiy and Yamal Peninsulas [6, 33]. The migration routes of the Siberian tundra bean geese are more distinct in East Tuva, near the Middle Angara River and in the areas to the east of Baikal [9, 19, 20].

The scattering area of both wintering grounds and nesting sites for different geese species and their population groups is very broad and diverse. However, the route direction of the predominant bird group is quite noticeable: N-W in spring and S-E in autumn. The exceptions are the flyways that pass through the Yenisei-Ob migration area where, in addition to the southern direction, one can observe the movements of *A.f. fabalis* and a part of *A. f. rossicus* species towards W and S-W. There is a quite noticeable autumn flyway of bean geese in the middle reaches of the Tym and Ket Rivers. In spring, many birds fly along the Eltyreva and Paydugina Rivers. In spring, in the Sym River basin, geese migrate towards both N-N-W and N-E. Some birds fly from the north-west towards southeast, using the riverbed as a guideline. In autumn, there are two apparent directions – W-S-W and S-S-E.

The Central Asia-Upper Yenisei-Ob flyway of bean geese passes through the continental regions of Inner Asia; it joins the Ubsunur Gobi-Qinghai and East Tuva-Khubsugul-Chinese routes in Inner Asia. The analysis of available information allows concluding that birds migrate to the basin of the Upper Yenisei, Mongolia and China through the Central Siberia from both Taimyr and the Middle Ob River basin. The main part of the birds using this flyway is the bean geese of the west tundra *A.f. rossicus* subspecies, which nest in the north of West Siberia and which can form, according to our opinion, a separate Tuva-Minusinsk subpopulation.

Generally, the registration of banded birds in Tomsk Region also confirms the flyway scheme of *A.f. rossicus*, which moves from the Middle Ob in the southeast direction.

In autumn, bean geese arrive to the Minusinsk Hollow from the northwest. One branch of this route (Tuva-Khakasiya) proceeds from the Chulym River basin to the south-south-east almost parallel to the Yenisei River, and crosses the West Sayan at the angle 130-140°, reaching the central part of the Tuva Hollow. Further, one part of the birds follows the east direction to the upper reaches of the Lower Yenisei River and the other one flies to the south east across East Tannu-Ola to the east edge of the Ubsunur Lake Hollow and then, up the Tes River, to Mongolia.

The other, Upper Yenisei-Chulym, branch of geese flyway goes through the Minusinsk Hollow directly to the southeast, along the line – city of Uzhur–Karatyzkoe village. Then, geese fly along the Amyl River valley that serves as a guideline and cross the east part of the West Sayan. Then, bean geese migrate to southeast along the north eastern foothills of Obruchev Range. They cross the Range at the Serlig-Hem River head, reach the Buseingol and Tere-Khol Hollows, continue flying along the Delgermörön River head to Mongolia. Through the upper reaches of the Eg and Selenga Rivers, bean geese follow the S-E direction and finally reach their wintering grounds located in the Yangtze River basin, China.

4. Discussion

The species composition of geese migrating through the south of Central Siberia includes 7 species. Their proportions, like the representation of bean geese species with regard to the indicated flyways, are different. This variation depends not only on migration routes genesis, but also on the nature of the present-day impact of natural and anthropogenic factors.

Until the mid-1980s, there were 3 species of bean geese, graylag (*Anser anser*) and bar-headed (*Eulabeia indica*) geese, and swan goose (*Cygnopsis cygnoides*) that could be found within the area of

the Minusinsk, Central Tuva and Todzha Hollows. Big flocks of white-fronted (*A. albifrons*) geese began to appear in the 1990s in the region as far as the Minusinsk Hollow. Both geese agglomerations and stopover places are marked by occasional presence of lesser white-fronted geese (*Anser erythropus*) and red-breasted geese (*Rufibrenta ruficollis*).

In the XX century, due to a reduction in the most important bean goose aggregations, the once actively used migration routes of this species became abandoned and even diapered. For example, the number of bean geese in the Lower Angara region decreased 2-3 times over the past 15-20 years, or more than 15 times as compared to the mid-1960s. This happens because of continuous degradation of the key wetlands, which are important elements of migration routes for the birds of Central Siberia.

The Central Asia migration route includes the flyways of grey geese that inhabit Central Siberia but migrate in different directions: from the Minusinsk Hollow to the west, and from the Ubsunur Hollow to the south.

The analysis of previously conducted collection works [5] revealed several morphological distinctions among graylag geese inhabiting these Hollows. It as ascertained that the geese of the Minusinsk Hollow are closely related to the birds inhabiting West Siberia (Lakes Chany and Kulundinskoye). It is possible to say that the territory north of the West Sayan is inhabited by graylag geese that belong to the West Siberia-Kazakhstan-Caspian-Mesopotamia geographical population (separated by A. Kischinsky in 1979). The Ubsunur hollow is inhabited by the geese that are related to West Mongolia and winter in India (the lower reaches of the Ganges) and Bengal [37]. Within the South Minusinsk, Todzha, Uyuk and Central Tuva Hollows, there are birds occupying the outlying districts of these groups' habitat areas, which primarily explains their natural paucity in the past and rapid vanishing in the south of Krasnoyarsk Krai and Khakassia [5; 34; 35]. There are no more than 300 graylag geese left in the south part of Krasnoyarsk Krai, Khakassia and the surrounding areas of Kemerovo Oblast. Not more than 1.5-2.0 thousand individuals are left in the wetlands of South Tuva (mainly the basin of Lake Ubsunur). The total number of this species has decreased by more than 3 times over the past decade. The inclusion of this species into the Red Data Books of both Krasnoyarsk Krai and the Republic of Khakassia has not yet given results. The main reason of the abundance reduction is excessive bird catching in the neighborhood regions.

The migration locations of East Tuva and the West Sayan are characterized by autumn transit migrations. Pre-flying clusters of Siberian taiga bean geese (99.6%) are formed near some reservoirs in August and September; the total proportion of graylag, bar-headed and swan geese species is only 0.4%. According to the survey data, tundra bean geese prevail in the Todzha and Tere-Khol Hollows in migration periods. Their flocks sometimes include groups of white-fronted geese -with the ratio approximately 1:150 to bean geese.

Numerous tundra (Bewick's) swans of the Gydan subpopulation migrate by the Tuva-Khakassia branch of the Central Asian migration route. This species' flyways match the routes of the *A. f. rossicus* species in most parts of the considered region, but on the territory of Mongolia, one of the branches passes through the Great Lakes Hollow along the Mongolian Altai. At about 100°E, tundra swans turn south where their route match the flyway of bar-headed geese tagged in the territory of Khövsgöl Province [23, 40].

According to recent data [44], the number of bean geese in eastern Asia is 157-194 thousand individuals, 18 thousand of them are *A.f. middendorffii* species. We think that these quantity is underestimated, probably due to exclusion of geese wintering in western China, central Asia and, partly, India. Taking into account territorial links and the geese number along migration routes, these territories, to our estimation, may be wintering areas for 15-40 thousand *A. f. fabalis* that inhabit the Yenisei-Ob and Yenisei-Taz interfluves, as well as the western parts of the Putorana Plateau, Syverma Plateau and some other adjoining areas of the Yenisei right bank.

Besides, not less than 25 thousand *A.f. rossicus* migrate for wintering from West Siberia's tundra areas and Taimyr to China. 13 thousand geese of *A.f. serrirostris* subspecies fly to the same direction from East Taimyr tundra zones and the Khatanga-Lena interfluve. Eastern taiga bean geese (*A.f. middendorffii*) inhabiting Evenkia, Zaangarie, western Yakutia and the north of Irkutsk Oblast (at least

15 thousand individuals) and the geese inhabiting the Altai-Sayan Ecoregion (1.5-2 thousand individuals) follow to wintering grounds to the lower reaches of the Yangtze river, most likely to Lake Dongting environs.

Thus, if the number of geese on the territory of Central Siberia, in our estimation, is 1732.3 thousand individuals, the total number of birds migrating along the indicated routes in the southern Central Siberia is only 106.85 thousand individuals, or 6.2% of all geese in the region.

5. Conclusion

It is believed that the most important Siberia's stopover places for birds migrating from north to south and back are situated in the valleys of the Ob, Yenisei and Lena Rivers [25]. This is only partially true with regard to the Yenisei, especially to its upper part. Only a comparatively small number of species and individuals flies in the southern direction, keeping to the meridional line of the river bed, overpassing the Sayan Mountains and then the upland deserts of Inner Asia [36]. Geese are likely to be an exception interns of species composition; they are broadly represented on the continental flyways of the southern Krasnoyarsk Krai, Khakassia and Tuva (Ubsunur Gobi-Qinghai и East Tuva-Khubsugul-Chinese flyways), but in terms of quantity, they form only 1.7% of the total number of geese inhabiting Central Siberia.

The Great Lakes basin in Mongolia is currently a kind of “migration dead end” for a great number of waterfowl migrating in spring; this situation did not change with formation of large reservoirs in the south of the region.

Obtaining the details of certain species/subspecies migration routes evidently requires using modern technologies or satellite tracking of tagged individuals. Unfortunately, such works were performed in the considered region for only few species, with a limited number of transmitters. At the same time, we have a substantial set of data on bird migration accumulated by traditional methods. This knowledge can now help in solving a number of problems related to conservation of several species of birds, as well as in ensuring the biological safety of the region.

Some well noticeable birds can be used as markers or tracers of migration routes, which was done in this study. For example, the flyways of *A.f. rossicus* (the Tuva-Minusinsk subpopulation) and *Cygnus bewickii* (the Gydan subpopulation) largely coincide. The tagging of tundra swans with satellite transmitters in Yamal in 2015 (<http://casarca.ru/proekty-rgg/91-proekty-rgg>) and 5 geese *A.f. middendorffii*, marked by us in the Altai-Sayan region (figure 2), confirmed the correctness of the scheme of migration flyways, obtained using traditional ornithological investigations.

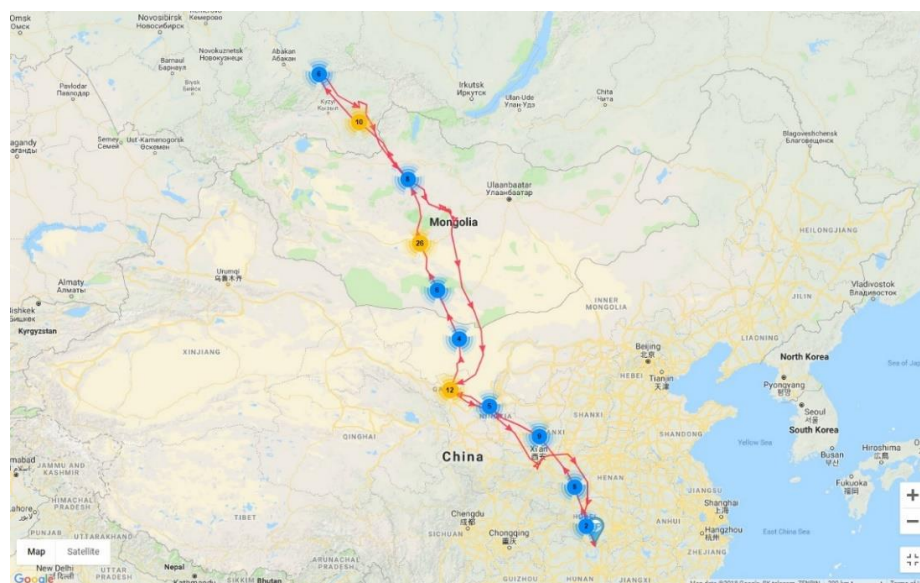


Figure 2. Migration route of *Anser fabalis middendorffii* marked in Altai-Sayan region.

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